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A PHOTOGRAPHIC METHOD FOR RECORDING SIZE OF SPRAY DROPS

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In analyzing the results of tests conducted with various types of equipment for spraying insecticides by airplane, we found evidence rather early that the degree of atomization was a governing factor in the lateral distribution of the deposit. A search of the literature indicated that the only method of determining a drop spectrum adequately was to measure and count the drops recovered in a sample of the spray. The requisite number of drops to be measured in an adequate sample increases tremendously as the drop size increases. Since we were dealing with sprays containing rather large drops, counting and measuring them with a microscope was exceedingly impractical. Therefore, we decided to avoid that method. Projected photographs appeared to offer the best possibilities. Since some sprays evaporate rapidly, we especially desired to develop a method in which the spray drops could be photographed in the field. The method evolved is essentially as described below.

Photographing the Drops

The samples are collected on microscope slides coated with an oleophobic film. In a typical test from 21 to 61 stations are prearranged at 10- or 20-foot intervals in a line perpendicular to the flight line, and three slides are placed at each station. Usually the falling spray covers only part of the line of stations. The spray is allowed to settle for 10 minutes after the plane has been flown over the sample line. The three slides from each station are then picked up and put in a clip to hold them parallel to each other. Each clip is placed in front of the lens of the camera, as shown in figure 1, with the middle slide in focus and the slides photographed. Only the middle third of each slide is recorded by this camera, which was developed especially for this work. The lens used most has a focal length of 4 3/4 inches but those of other focal lengths can be employed, depending on the magnification required. The bellows is rigid, being a plywood box with shields inside to subdue reflections from the sides. The film is held in the back by a 4- by 5-inch

film-pack adapter. This combination always gives the same magnification (about 4 times), since nothing is adjustable.

The camera is shown in figure 2. Beyond the lens is a circular target centered on the optical axis. The size and placing of this target should be such that its image just completely covers the negative at the lens stop used. The one shown here is 5 5/8 inches in diameter and is 21 inches from the lens. This arrangement gives negatives of high contrast, in which the background is transparent and the images of the drops are black circles or crescents. The exposures are made with the optical axis pointing directly at the sun. At f:64 1- or 2-second exposures are used for most panchromatic films on days of average brightness, and longer exposures under overcast conditions. At f:64 the depth of focus is sufficient to include the three slides used. Drops on the near slides will occasionally conceal a drop on a more distant slide, but the resulting error is negligible. With a somewhat larger f number, this camera has been used to photograph as many as eight slides simultaneously. Figure 3 illustrates the type of record obtained with this camera.

If the spray consists of relatively small drops, having a mass median diameter [1/] of less than 100 microns, a 2-inch focal-length lens is substituted for the 4 3/4-inch lens, and a 2 1/2-inch target at about 12 inches is substituted for the 5 5/8-inch target at 21 inches. Only one slide is used, because at this magnification it is difficult to get depth of focus for more than one. One slide provides a sufficient sample, since the smaller drops are more uniform and fewer are needed. With this larger magnification also a smaller area is included in the photograph, but with smaller drops there are many more drops per unit area. It is possible that lenses of still shorter focal length could be used with very small drops, but we have not had occasion to measure drops where the mass median diameter was less than about 80 microns.

The apparatus described is usable when the smallest drops to be measured are about 30 microns in diameter. The mass median diameter is then usually greater than 100 microns. With the 2-inch focal-length lens the range is somewhat less than half the range with the 4 3/4-inch lens.

Measuring and Counting the Drops

The drops are measured and counted on a projection of the photographic negative. A cold-light photographic enlarger was altered so as to project upward from below onto a ground-glass table top. The time required to

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1/ The mass median diameter is the drop diameter which satisfies the condition that half the volume of spray is in drops larger and half in drops smaller than it.

count and measure the drops on one negative is usually too great to allow use of a conventional enlarger; hence the cold light was used. The over-all magnification of camera and projector must be known. We determine this by photographing the jaws of a vernier caliper set at exactly 1 inch or other convenient length and then measuring the final projection of this opening. We use a magnification of 14.25, but this value has no particular merit over any other. The diameters of the drop images are measured, and the images classified according to size. Each class has a diameter range of 1 mm., i.e., 0.5 mm. smaller and larger than the unit specified. These data are combined and totaled for all stations in the flight and sometimes for several flights, and the average-drop spectrum computed.

Determination of Spread Factor

In order to determine the actual size of the drops, it is necessary to know the spread factor, or the number of times larger the resting drops are than the spherical drops from which they resulted. This spread factor is determined by a method similar to one described by May (1). This method involves two steps--(1) measurement by microscope of the diameters and focal lengths of a few representative drops, and (2) determination of the index of refraction of the material. It has been found advisable to tap the slide a few times with a pencil or fingernail before making microscope measurements to help the drops establish their equilibrium shape. The data are somewhat scattering; nevertheless, one is able to determine the average ratio, which is assumed to be a straight line with drops of the size ordinarily encountered. A vertical line upward from the point on the nomograph (fig. 5) where this straight line intersects the line of constant index refraction gives the value of the spread factor on the scale at the top.

Computations

The product of the spread factor and the over-all magnification represents the number of times larger the images are than the original spherical drops. The micron size is found for each class by multiplying the class size by 1,000 and dividing by the product mentioned.

Each class size is cubed and multiplied by the number of drops in the class. These products are then expressed as percentages of the total and cumulated. The size corresponding to the 50-percent cumulation is the mass median diameter. The sizes corresponding to 25- and 75-percent cumulations indicate the range of size represented by the middle 50 percent of the volume deposited.

In determining these various points we found it convenient to plot the cumulative volume percent against the micron size on log-probability paper, as shown in figure 4. On this curve the mass median diameter is

seen to be 237 microns and the diameter range of the middle 50-percent volume is 164 to 353 microns. In the class having the smallest diameter the images of the drops may be confused with those of dust particles, pollen grains, etc. Therefore, data for this class are usually discarded. Although there may be a large number of these drops, they do not represent much volume, and the mass median diameter and the middle 50-percent volume are affected only very slightly when they are discarded.

Advantages of the Photographic Method

(1) It provides a permanent record which can be measured when convenient.
(2) It is fairly rapid. Two workers can tabulate several thousand drops per hour.
(3) It is fairly clean, involving no smoke or coatings other than oleophobic material, which is simple to use, and is readily obtainable.
(4) It avoids errors due to evaporation from drop surfaces.

Literature Cited

(1) May, K. R.
1945. The cascade impactor; an instrument for sampling coarse aerosols. Jour. Sci. Instr. 22(10): 187.

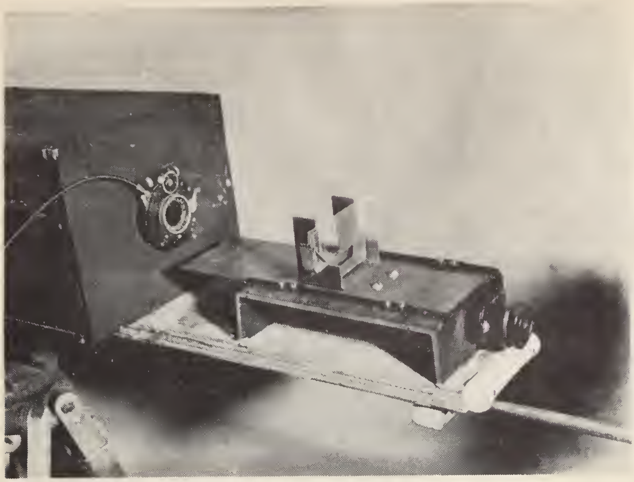

Figure 1.-- Three paralled slides mounted in the field of the camera lens.

Figure 2.--Camera for recording drop size of aerial sprays.

Figure 3.--Sample photographic record of drops collected on three microscope slides.

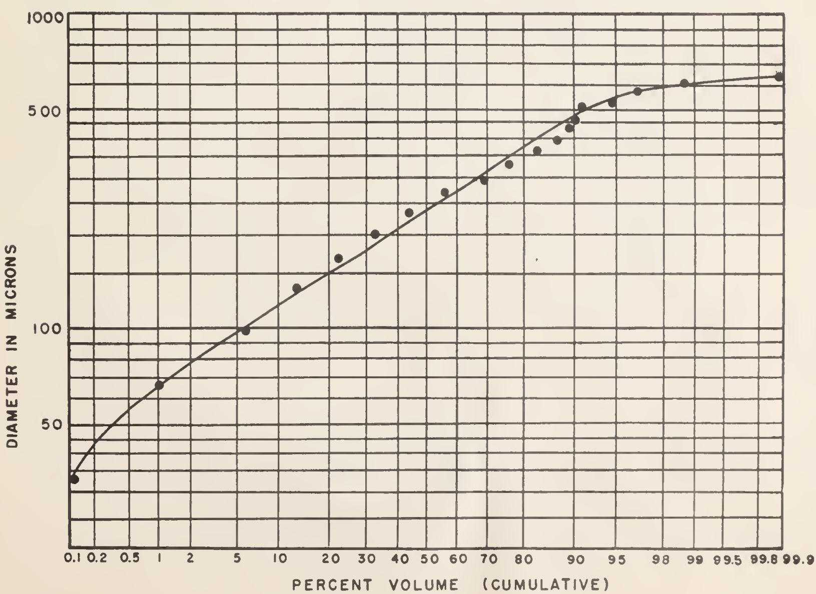

Figure 4.--Cumulative percent volume plotted against diameter of drops.

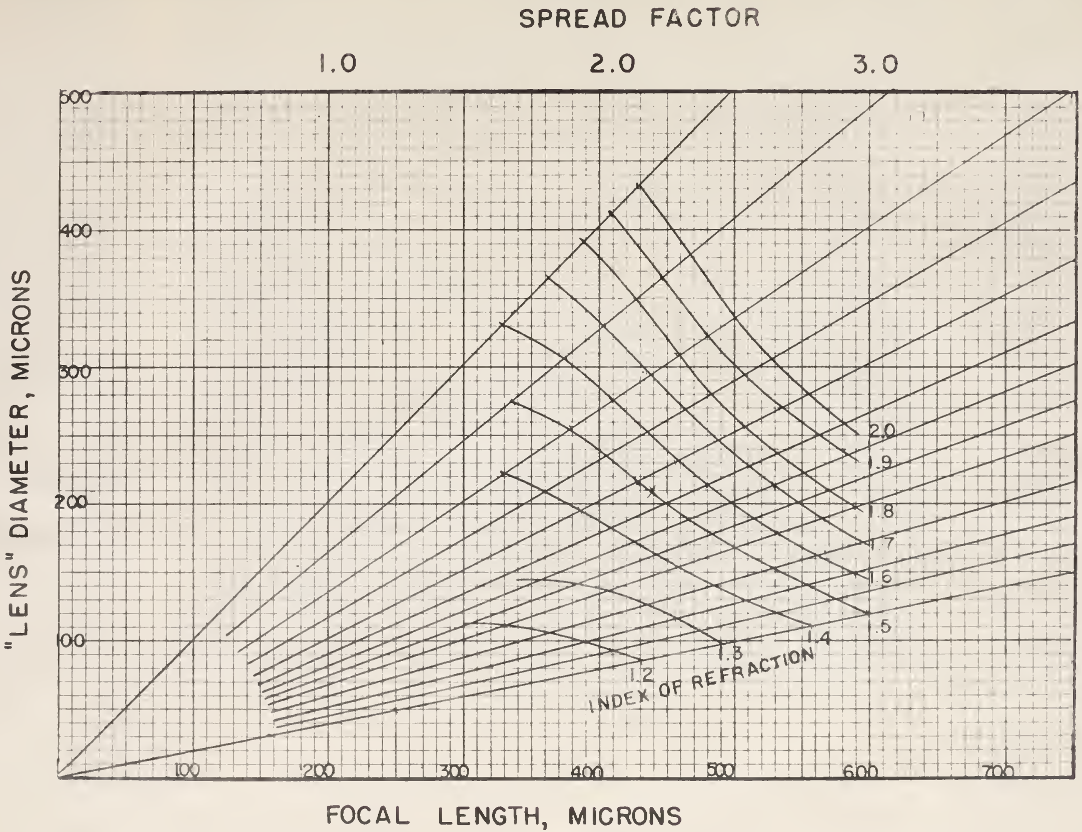

Figure 5.--A chart for determining the spread factor when the index of refraction of the material and the ratio of focal length to the diameter of resting drops are known